CHAPTER 6

ASSOCIATED ANTENNA COMPONENTS

The performance of any antenna system is dependent not only upon the antenna, but also upon the components used with the antenna. Transmission lines, impedance matching devices, dissipation and terminating devices, multicouplers, and lightning protection devices must be properly designed and installed in order to achieve satisfactory antenna performance.

6.1 TRANSMISSION LINES

The type of transmission line chosen for a particular application depends primarily upon the operating power level, characteristic impedance, line losses, and susceptibility to RF interference.

There are two basic types of transmission lines; balanced and unbalanced.

6.1.1 Balanced Transmission Lines

Balanced lines consist of two separate conductors operated at equal and opposite potentials. Balanced lines are usually open-wire configurations except where shielding may be a requirement; e.g., at building entry points, or for RF distribution inside the building.

Open-wire lines provide good balance, constant characteristic impedance and low loss, and they are capable of handling very high power levels. Although coaxial cable has largely replaced open-wire lines at HF radio installations, open-wire lines still provide a practical, relatively low-cost solution to RF-power transmission requirements. This is particularly true for high-power applications when unusually long distances between the transmitter and antenna are necessary.

a. Physical and Electrical Characteristics. The most commonly used balanced transmission line is the 600-ohm open-wire configuration consisting of two No. 6 AWG copper-clad steel wires spaced 12 inches apart, but there are variations, including those illustrated in figure 6-1, which will provide greater power handling capability. For example, compared to the two-wire line, the side-connected four-wire line has a lower characteristic impedance, higher power handling capability, and lower attenuation. By adjusting the wire size, and the number and arrangement of conductors the open-wire transmission line can be designed with the desired power handling capability, characteristic impedance, and attenuation. No. 6 copper-clad steel wire has the necessary tensile strength and degree of conductivity; however, care must be taken during installation to insure that the copper coating is not broken since such damage can result in rust and ultimate failure of the line. Some naval shore stations have used No. 8 wires spaced 6 inches apart for interior runs to minimize coupling and conserve space. In such cases the line is tapered gradually to meet No. 6 wires, spaced 12 inches apart, outside the transmitter building, thus changing to the lower attenuation and greater tensile strength of the larger diameter wire.

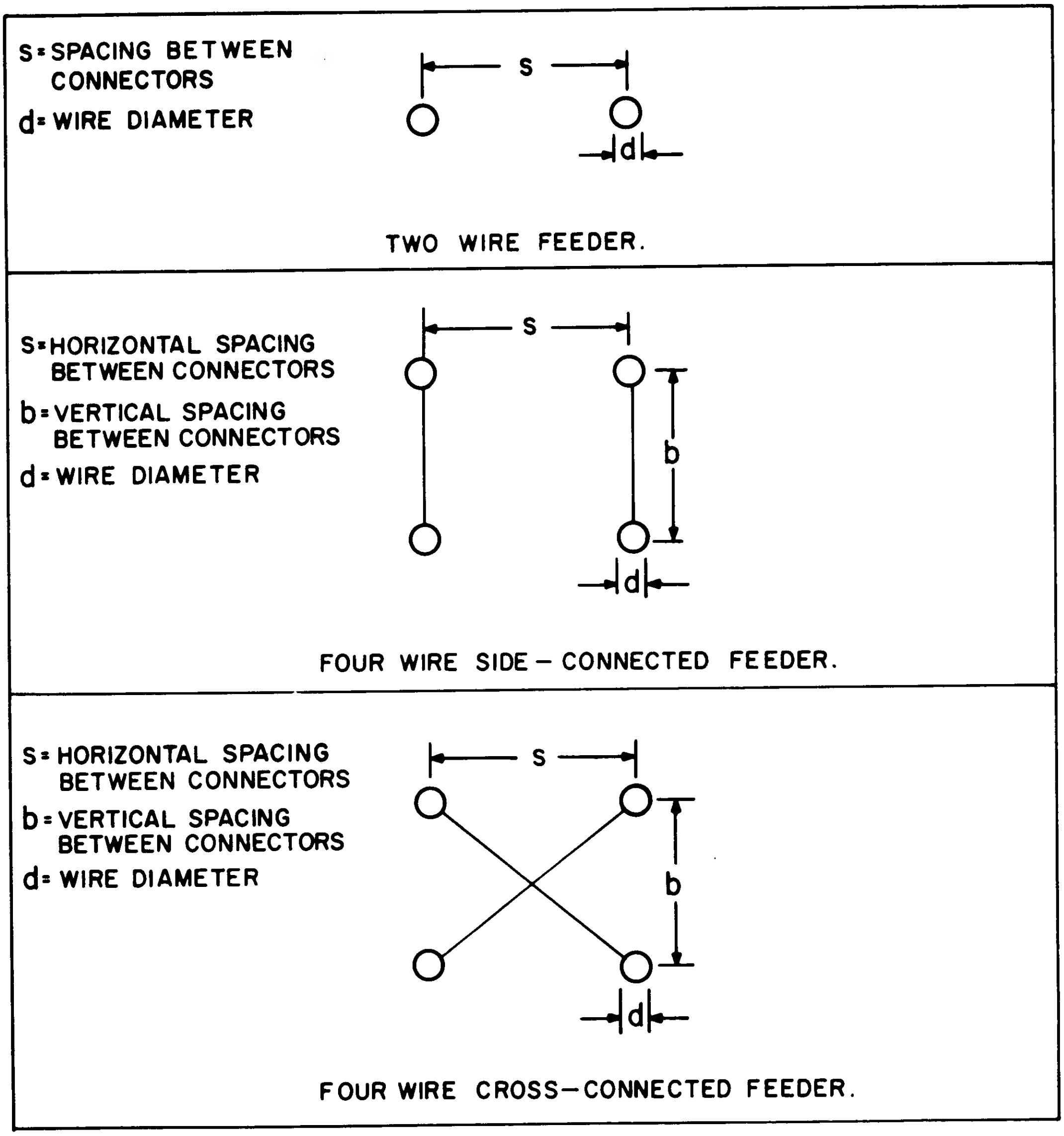

Figure 6-1. Open-Wire Transmission Line Configurations

(1) Power Losses. Losses from a balanced transmission line include direct radiation from the line, insulation losses (leakage), and losses due to the resistance of the wire (copper losses). Radiation losses are usually negligible if the line is terminated at or near its characteristic impedance. Leakage losses are determined to a great extent by the configuration, materials, and the care exercised in construction, and these losses will also vary with the condition of insulators and with weather effects such as icing. Leakage losses in a long open-wire transmission line can range from approximately 20 to 70 percent of the resistance losses which are determined by the wire size and the frequency of the current in the wire. Attenuation of a two-wire copper line, excluding insulator and radiation losses, is given by the expression:

$$a = \frac{14.4\sqrt{f}}{dZ_o} \text{ dB/1000 ft.} \qquad (6\text{-}1)$$

where a = attenuation in dB per 1000 feet of two-wire line
f = frequency in MHz
d = diameter of conductors in inches
Z_o = characteristic impedance of the line

For the Navy standard 600-ohm line using No. 6 wire this reduces to:

$$a = 0.148\sqrt{f} = \text{dB/1000 ft.} \qquad (6\text{-}2)$$

This equation is plotted in figure 6-2 to illustrate how attenuation varies with frequency, and to show the range of values to be expected over the HF band.

(2) Characteristic Impedance. The characteristic impedance of an open-wire transmission line varies directly with the spacing between the wires, inversely with the diameter of the wires, and inversely with the square root of the dielectric constant of the insulating material. Since air is the insulating material and its dielectric constant is 1, this factor is not normally considered in the design of open-wire lines. The characteristic impedance can also be affected by the height of the line above ground but the effect is negligible as long as the transmission line is suspended at least 10 feet above the ground.

(3) VSWR. The VSWR of open-wire lines must not exceed 1.1:1 over the operating frequency bandwidth.

(4) Power Handling Capability. Voltage, rather than current, is the principal factor limiting the power on open-wire transmission lines. The maximum RF voltage that can be applied safely on an open-wire line depends upon:

(a) The spacing of the wires

(b) The type, size, and condition of insulators

(c) Height above sea level, temperature, and humidity (which, in turn, affect the voltage level where corona discharge and voltage breakdown occur).

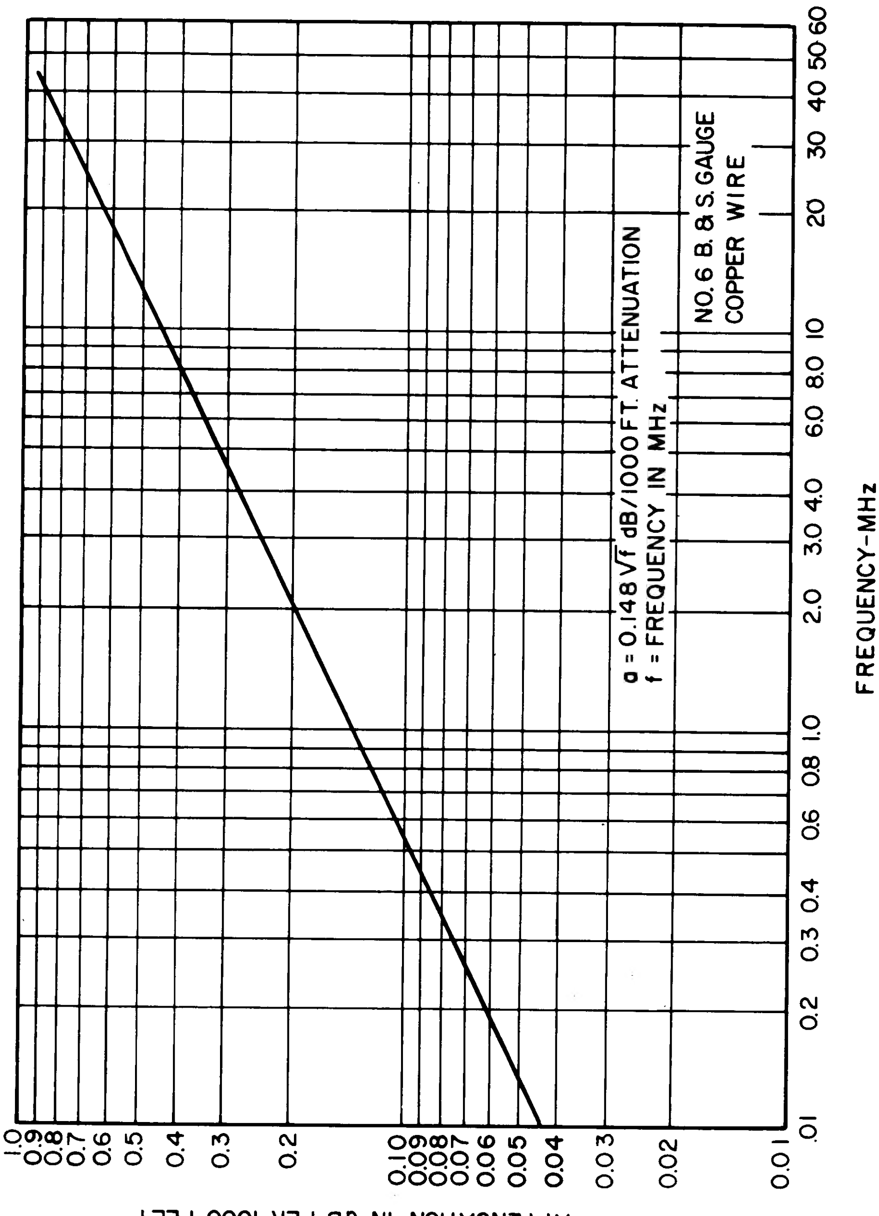

Figure 6-2. Attenuation of 600-Ohm Parallel Wire Line

Figure 6-3 shows that the standard 600-ohm line constructed of No. 6 wire is capable of handling average power inputs of about 90 kW. The data in figure 6-3 allow a 2.5 safety factor which should accommodate most variations of temperature, humidity, and atmospheric pressure. The 90 kW capacity of the standard two-wire line constructed of No. 6 wire, with 12-inch spacing between conductors has been found to be sufficient for most Navy installations. In the event that an installation requires an open-wire line with greater power handling capability, the four-wire side- or cross-connected variations shown in figure 6-1 should be considered.

b. Installation and Construction Considerations. Installation of open-wire systems is not contemplated for new facilities because all new transmitters and receivers are designed for 50-ohm transmission lines. However, it is likely that existing open-wire lines will continue to fulfill requirements for some time to come. For this reason and for special requirement contingencies, the significant factors for installing and maintaining a well-designed two-wire open transmission line are included here. Detailed construction and installation information is contained in BUSHIPS Drawing RE 10F 2143 Rev. G, and the procedures for matching open-wire lines to half-wave antennas are presented in appendix A.

(1) Choose wire of sufficient mechanical strength to withstand the stresses of wind, ice, etc. (refer to table 7-5 for the breaking load of different wire sizes).

(2) Choose wire with acceptable resistance losses.

(3) Space the conductors adequately to prevent corona and voltage breakdown between conductors. (Standard spacing for No. 6 copper-clad steel wire is 12 inches.)

(4) Keep the total length of each conductor of a balanced line exactly equal.

(5) Make no connections that will unbalance the line. If connectors or tie-wires are installed on one conductor, install the exact duplicate on the other conductor at the same electrical point.

(6) To minimize ground losses, install open-wire lines at least 10 feet above ground.

(7) To minimize mutual coupling, maintain a vertical separation of at least 10 feet between transmission lines, and ensure that there is a horizontal distance of at least ten line-spacings between centers of all lines.

(8) Avoid sharp turns or bends. Any necessary turn should take the form of a gradually curving path.

(9) To avoid undesirable coupling, do not run open-wire lines under antennas or parallel to pole-mounted power or telephone lines.

(10) To reduce the possibility of resonant line sections, stagger individual span-lengths so that no parallel spans are the same length.

(11) For installation of new equipment designed for 50-ohm coaxial transmission lines, use baluns to connect open-wire lines to coaxial lines inside the building.

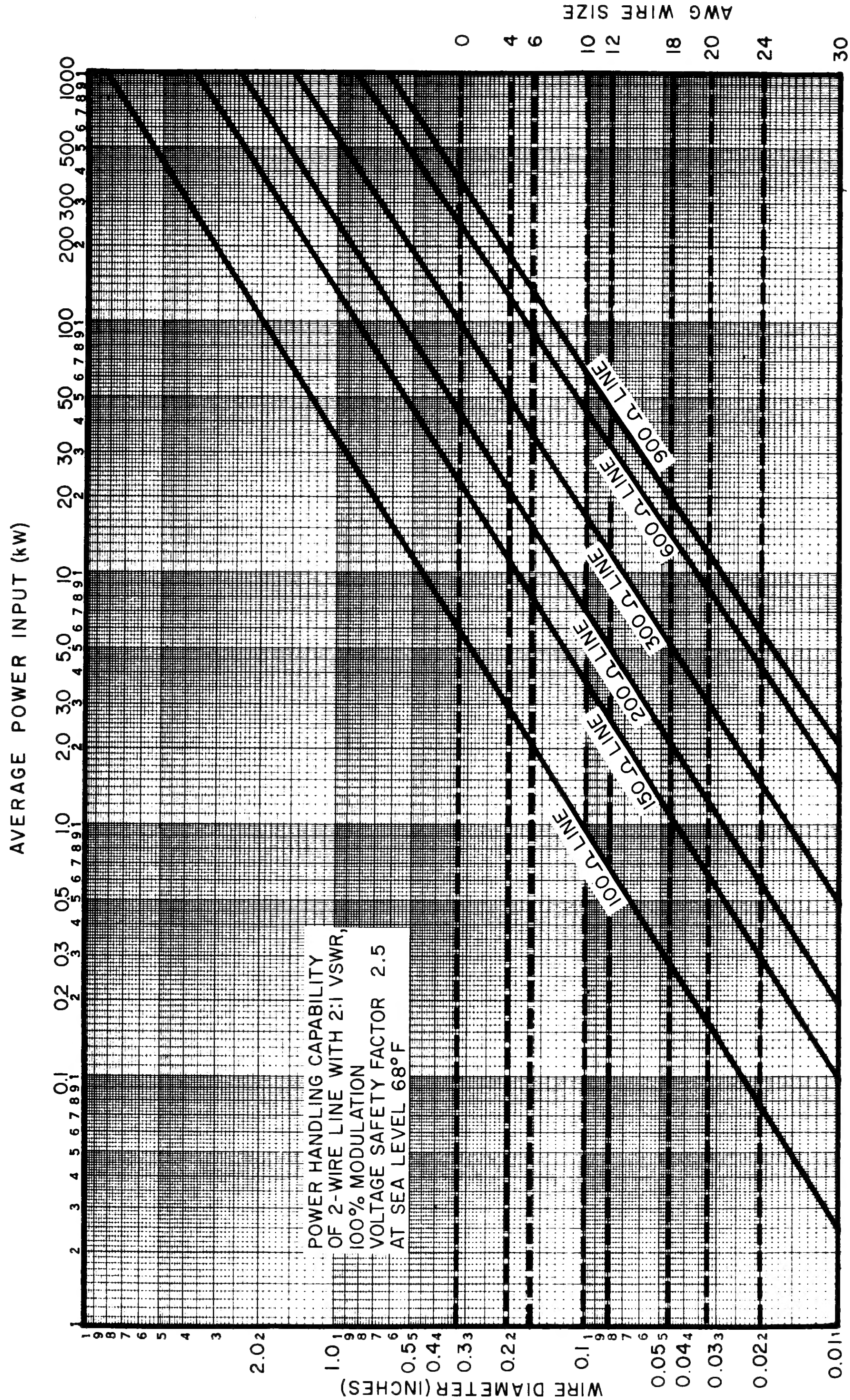

Figure 6-3. Power Handling Capability of Two-Wire Lines

6.1.2 Unbalanced Transmission Lines

Coaxial cables used in HF transmitter and receiver installations operate with the center conductor at a potential above ground and the shield (outer conductor) at ground potential, and, therefore, are unbalanced transmission lines.

Even though coaxial cable is more expensive and has a higher attenuation per unit length than the open-wire transmission lines, the advantages of coaxial lines normally outweigh those of the open-wire lines. Some of these advantages are the relative ease of installation, simplicity of building entry, and elimination of noise pickup over the length of the line. Coaxial lines also make possible a simplified method of switching between transmitters and antennas.

Coaxial transmission lines are used almost exclusively at all receiving installations, and in most transmitting applications. Fifty-ohm cable, the standard characteristic impedance for Navy applications, is available in sufficient variety to meet the requirements for Navy HF transmitter and receiver installations.

Coaxial lines are normally buried for the length of the run from the point of antenna termination to building entry. However, there are some cases in which installations above ground are advantageous.

a. Physical and Electrical Characteristics. Three types of coaxial cables are used for HF transmission lines: flexible, semi-flexible, and rigid. Flexible and semi-flexible cables are commonly used in receiver and transmitter installations, whereas rigid cable is used only for certain applications inside transmitter buildings, and in some very high power installations.

The physical size of coaxial cables varies widely, and signal attenuation generally decreases with increasing diameter. The outer diameter of flexible cable ranges from approximately 1/8 to 1-1/4 inches; semi-flexible cable may be as large as 8 inches; and rigid cable varies from 6 to 9 inches. At 30 MHz, the attenuation in dB per 1000 feet ranges from 2 to 30 for the 1/8 to 1-1/4 inch sizes, is approximately 0.4 for a 5-inch semi-flexible line, and is approximately 0.3 dB for the 6- to 9-inch rigid sizes. The attenuation rates for many of the conventional coaxial cables, calculated over a 1 to 100 MHz incremental frequency range, are listed in table 6-1. Obsolete cable types are included in the table to aid in cross-reference identification with new cable data.

A nominal value of characteristic impedance is designed into each cable type. This value, and other significant physical and electrical data on preferred RF cables are presented in table 6-2, and in reference 16. If it becomes necessary to determine the characteristic impedance of a cable the calculation may be made by using the following equations:

For air dielectric cable,

$$Z_o = 138 \log_{10} \frac{s}{d} \qquad (6\text{-}3)$$

For solid dielectric cable,

$$Z_o = \frac{138 \log_{10} \frac{s}{d}}{\sqrt{\epsilon}} \quad (6\text{-}4)$$

where Z_o = characteristic impedance
ϵ = dielectric constant
s = inner diameter of outer conductor
d = outer diameter of inner conductor

Flexible and semi-flexible cables may be procured in continuous lengths to match the length of transmission line needed to avoid splices, and they may be stored on reels until time for installation. Rigid cable is manufactured in standard 20-foot lengths and it comes equipped with interconnecting flanges.

Most rigid lines and some semi-flexible lines are first purged and then pressurized to reduce attenuation and increase the maximum permissible voltage rating. Purging is usually accomplished with dry nitrogen gas although dry air may be substituted when the size of the cable makes the use of nitrogen extremely expensive. Once a coaxial cable has been purged, pressure is usually maintained on the line with a dry air system. Operating the cable under pressure also helps prevent moisture from entering the line and thereby lowering the insulation resistance.

(1) Power Losses. Power losses in coaxial transmission lines are caused primarily by the resistance of the center conductor. In a high quality coaxial cable, attenuation loss is approximately three times that of a properly designed and installed two-wire balanced line. Other factors which contribute to coaxial line power losses are:

(a) Impedance mismatches in the line

(b) Excessive distance between the antenna and the transmitter or receiver

(c) Installation deficiencies (sharp bends, improper splices, faulty end-seals and connectors, etc.)

(2) Characteristic Impedance. For Navy applications, coaxial cable with a characteristic impedance of 50 ohms has been adopted as standard in accordance with BUSHIPS letter 9670/1-2, serial 679D-34 of 2 February 1962, "Radio Frequency Coaxial Cable Transmission Line; standardization on characteristic impedance of." Since the terminal impedance of various system components affects the design of other components as well as the design and performance of the overall system, adoption of a standard impedance is both technically and economically prudent.

(3) VSWR. The VSWR of coaxial transmission lines must not exceed 1.1:1 over the operating frequency bandwidth.

Table 6-1. Attenuation of Conventional Coaxial Cables in dB per 100 Feet

RG-( )/U	1 MHz	10 MHz	30 MHz	100 MHz
*5	0.21	0.77	1.5	2.9
*5A	0.16	0.66	1.25	2.4
5B	0.16	0.66	1.25	2.4
*6	0.21	0.78	1.46	2.8
6A	0.21	0.78	1.46	2.9
*7	0.17	0.65	1.20	2.4
8	0.16	0.55	1.0	2.0
*8A	0.16	0.55	1.0	2.0
9	0.16	0.57	1.02	2.0
9A	0.175	0.61	1.12	2.1
*9B	0.175	0.61	1.12	2.1
10	-	0.55	1.0	2.1
10A	0.16	0.55	1.0	2.0
11	0.18	0.66	1.2	2.3
11A	0.18	0.66	1.2	2.3
12	-	0.62	1.15	2.1
12A	0.18	0.66	1.2	2.3
13	0.18	0.66	1.2	2.3
*13A	0.18	0.66	1.2	2.3
14	0.12	0.41	0.74	1.4
*14A	0.12	0.41	0.74	1.4
15	0.17	0.31	0.86	1.58
16	-	-	-	1.2
17	0.066	0.225	0.41	0.80
*17A	0.066	0.225	0.41	0.80
17B	NEW NOMENCLATURE RG-177/U			
18	0.066	0.225	0.41	0.80
*18A	0.066	0.225	0.41	0.80
19	0.04	0.17	0.33	0.68
*19A	0.04	0.17	0.33	0.68
20	-	-	-	0.68
*20A	0.04	0.17	0.33	0.68
21	1.4	4.4	7.4	13.0
*21A	1.4	4.4	7.4	13.0
22	0.41	1.3	2.4	4.3
22B	0.42	1.3	2.2	4.0
23	-	0.4	0.8	1.7
23A	-	0.4	0.8	1.7
24	-	0.4	0.8	1.7
24A	-	0.4	0.8	1.7
*29	0.33	1.2	2.2	4.4
34	0.065	0.29	0.6	1.3
34A	0.065	0.29	0.6	1.3
34B	-	0.22	0.42	0.85
35	0.07	0.24	0.43	0.85
35A	0.07	0.24	0.43	0.85
35B	-	0.22	0.42	0.85
*42	1.8	5.6	-	17.0
54A	0.18	0.74	1.4	3.1
55	0.36	1.3	2.4	4.8
55A	-	1.3	2.4	4.8
55B	-	1.3	2.4	4.8
57	-	-	1.4	3.0
57A	-	0.71	1.4	3.0
58	0.33	1.25	2.35	4.65
58A	0.42	1.6	3.0	6.2
58B	-	1.0	2.0	4.2
58C	0.42	1.6	3.0	6.2
59	0.34	1.1	1.85	3.4
59A	0.34	1.1	1.85	3.4
59B	-	1.1	2.0	3.8
62	0.25	0.85	1.5	2.7
62A	0.25	0.85	1.5	2.7
62B	-	0.83	1.5	2.7
*63	0.19	0.61	1.05	2.0
63A	-	0.6	1.1	2.0
63B	0.19	0.61	1.05	2.0
65	5.5	21.5	40.0	-
65A	5.5	21.5	40.0	-
71	0.25	0.85	1.5	2.7
71A	0.25	0.85	1.5	2.7
71B	-	0.83	1.5	2.7
74	-	0.38	0.73	1.5

RG-( )/U	1 MHz	10 MHz	30 MHz	100 MHz
74A	-	0.38	0.73	1.5
79	-	0.61	1.1	2.0
79B	-	0.6	1.1	2.0
83	0.2	0.80	1.45	2.8
*87	0.18	0.60	1.08	2.05
*87A	-	0.52	0.98	2.0
89	-	0.61	1.05	2.0
*94	-	-	-	-
94A	-	-	-	-
111A	-	1.3	2.2	4.0
114	0.95	1.35	1.72	2.90
114A	0.95	1.35	1.72	2.90
115	0.17	0.59	1.05	2.05
115A	0.17	0.59	1.05	2.05
*116	0.18	0.60	1.08	2.05
*117	0.067	0.245	0.45	0.90
117A	-	0.20	0.40	0.85
*118	0.067	0.245	0.45	0.90
118A	-	0.20	0.40	0.85
119	0.125	0.43	0.78	1.5
120	0.125	0.43	0.78	1.5
122	0.40	1.70	3.3	7.0
126	3.2	9.0	15.0	25.0
140	-	1.03	1.8	3.3
141	0.34	1.13	2.0	1.8
141A	-	1.12	2.0	3.8
142	0.34	1.13	2.0	1.8
142A	-	1.12	2.0	3.8
142B	-	1.12	2.0	3.8
143	0.25	0.83	1.45	2.8
143A	-	0.77	1.33	2.5
144	-	0.53	0.95	1.80
147	-	-	-	0.68
148	-	-	-	2.1
164	-	0.22	0.42	0.85
165	0.18	0.6	1.08	2.05
166	0.18	0.6	1.08	2.05
174	-	2.3	4.3	8.0
177	-	0.24	0.45	0.95
178B	-	4.0	6.6	12.8
179B	-	3.8	5.1	7.9
180B	-	2.2	3.7	6.6
187	-	3.8	5.1	7.9
187A	-	3.8	5.1	7.9
188	-	2.7	4.1	7.7
188A	-	2.7	4.1	7.7
195	-	2.2	3.7	6.6
195A	-	2.2	3.7	6.6
196	-	4.0	6.6	12.8
196A	-	4.0	6.6	12.8
211A	-	0.20	0.40	0.85
212	-	0.66	1.25	2.4
213	-	0.55	1.0	2.0
214	-	0.59	1.1	2.9
215	-	0.55	1.0	2.0
216	-	0.62	1.15	2.2
217	-	0.38	0.73	1.5
218	-	0.24	0.45	0.95
219	-	0.24	0.45	0.95
220	-	0.17	0.33	0.68
221	-	0.17	0.33	0.68
222	-	4.4	7.6	14.0
223	-	1.3	2.4	4.8
224	-	0.38	0.73	1.5
225	-	0.52	0.98	2.0
227	-	0.52	0.98	2.0
228A	-	0.20	0.40	0.85
301	-	9.0	15.0	25.0
302	-	1.03	1.8	3.3
303	-	1.12	2.0	3.8
304	-	0.77	1.33	2.5
316	-	2.7	4.1	7.7

*Obsolete

Table 6-2. Guide to Selection of Preferred RF Cables

Class of cables	JAN type	Inner conductor	Dielectric material	Nominal diameter of dielectric	Shielding braid	Protective covering	Nominal over-all diameter	Weight	Approx-imate imped-ance	Nominal capaci-tance	Maximum operating voltage	Remarks
				Inch			Inch	lb/ft	Ohms	$\mu\mu f/ft$	Volts/(rms)	
GENERAL PURPOSE	RG-6A/U	21 AWG copper covered steel	A	0.185	Inner, silver coated copper; Outer; copper	IIa	0.332	---	76.0	20.0	2,700	Small size, video and communication cable
	RG-11A/U	7/26 AWG tinned copper	A	0.285	Copper, single braid	IIa	0.412	---	75.0	20.5	5,000	Medium size, flexible video cable
	RG-12A/U	7/26 AWG tinned copper	A	0.285	Copper, single braid	IIa with armor	0.475	---	75.0	20.5	5,000	Similar to RG-11A/U but with armor
	RG-34B/U	7/0.0249 in. copper	A	0.460	Copper, single braid	IIa	0.630	0.231	75.0	21.5	6,500	Large size, high power, low attenuation, flexible cable
	RG-35B/U	.1045 in. copper	A	0.680	Copper, single braid	IIa with armor	0.945 (max)	0.480	75.0	21.5	10,000	Large size, high power, low attenuation, video and communication cable
	RG-55B/U	.032 in. silver covered copper	A	0.116	Silver covered copper, double braid	IIIa	0.206	0.032	53.0	28.5	1,900	Double braid small size cable
	RG-58C/U	19/.0071 in. tinned copper	A	0.116	Tinned copper, single braid	IIa	0.195	0.029	50.0	28.5	1,900	Small size, flexible cable
	RG-59B/U	.0230 in. copper covered steel	A	0.146	Copper, single braid	IIa	0.242	---	75.0	21.0	2,300	General purpose, small size, video cable
	RG-84A/U	.1045 in. copper	A	0.680	Copper, single braid	IIa with lead sheath	1.000	1.325	75.0	21.5	10,000	Same as RG-35B/U except lead sheath instead of armor for subterranean installations
	RG-85A/U	.1045 in. copper	A	0.680	Copper, single braid	IIa with lead sheath and special ar.	1.565 (max)	2.910	75.0	21.5	10,000	Same as RG-84A/U with special armor for subterranean installations
	RG-164/U	.1045 in. copper	A	0.680	Copper, single braid	IIa	0.870	0.490	75.0	21.5	10,000	Same as RG-35B/U except without armor
	RG-212/U	.0556 in. silver covered copper	A	0.185	Silver coated copper; double braid	IIa	0.332	0.093	50.0	28.5	3,000	Small size, microwave cable. Formerly RG-5B/U.
	RG-213/U	7/.0296 in. copper	A	0.285	Copper, single braid	IIa	0.405	0.120	50.0	29.5	5,000	Medium size, flexible cable. Formerly RG-8A/U.
	RG-214/U	7/.0296 in. silvered copper	A	0.285	Silver coated copper; double braid	IIa	0.425	0.158	50.0	30.0	5,000	Special, medium size, flexible cable. Formerly RG-9B/U.
	RG-215/U	7/.0296 in. copper	A	0.285	Copper, single braid	IIa with armor	0.475 (max)	0.160	50.0	29.5	5,000	Same as RG-214/U but with armor. Formerly RG-10A/U.
	RG-216/U	7/.0159 in. tinned copper	A	0.285	Copper, double braid	IIa	0.425	0.121	75.0	20.5	5,000	Medium size, flexible video and communication cable. Formerly RG-13A/U.

Table 6-2. Guide to Selection of Preferred RF Cables (Continued)

Class of cables	JAN type	Inner conductor	Dielectric material	Nominal diameter of dielectric	Shielding braid	Protective covering	Nominal over-all diameter	Weight	Approximate impedance	Nominal capacitance	Maximum operating voltage	Remarks
				Inch			Inch	lb/ft	Ohms	$\mu\mu f$/ft	Volts/(rms)	
GENERAL PURPOSE	RG-217/U	.106 in. copper	A	0.370	Copper, double braid	IIa	0.545	0.236	50.0	29.5	7,000	Medium size, power transmission line. Formerly RG-14A/U.
	RG-218/U	.195 in. copper	A	0.680	Copper, single braid	IIa	0.870	0.491	50.0	29.5	11,000	Large size, low attenuation, high power transmission line. Formerly RG-17A/U.
	RG-219/U	.195 in. copper	A	0.680	Copper, single braid	IIa with armor	0.945 (max)	0.603	50.0	29.5	11,000	Same as RG-218/U but with armor. Formerly RG-18A/U.
	RG-220/U	.260 in. copper	A	0.910	Copper, single braid	IIa	1.120	0.745	50.0	29.5	14,000	Very large, low attenuation, high power transmission cable. Formerly RG-19A/U.
	RG-221/U	.260 in. copper	A	0.910	Copper, single braid	IIa with armor	1.195 (max)	0.925	50.0	29.5	14,000	Same as RG-220/U but with armor. Formerly RG-20A/U.
	RG-223/U	.035 in. silver covered copper	A	0.116	Silver covered copper, double braid	IIa	0.216	0.036	50.0	28.5	1,900	Double braid small size cable. Formerly RG-55A/U.
	RG-224/U	.106 in. copper	A	0.370	Copper, double braid	IIa with armor	0.615 (max)	0.282	50.0	29.5	7,000	Same as RG-217/U but with armor. Formerly RG-74A/U.
HIGH TEMPERATURE	RG-115/U	7/.028 in. silver covered copper	F-2	0.250	Silver covered copper, double braid	Teflon tape moisture seal with double braid type V jacket	0.375	---	50.0	29.5	5,000	Double braid medium size cable, for use where expansion and contraction are a major problem.
	RG-140/U	.025 in. silver coated copper covered steel	F-1	0.146	Silver covered copper, single braid	Teflon tape moisture seal with single braid type V jacket	0.233	0.045	75.0	21.0	2,300	Similar to RG-59/U, except cable core is teflon
	RG-141A/U	.039 in. silver coated copper covered steel	F-1	0.116	Silver covered copper, single braid		0.190	0.030	50.0	28.5	1,900	Small size flexible cable
	RG-142A/U	.039 in. silver coated copper covered steel	F-1	0.116	Silver covered copper, double braid		0.206	0.045	50.0	28.5	1,900	Small size flexible cable
	RG-143A/U	.059 in. silver coated copper covered steel	F-1	0.185	Silver covered copper, double braid	Teflon tape moisture seal with double braid type V jacket	0.322	0.102	50.0	28.5	3,000	Similar to RG-212/U except cable core is teflon
	RG-144/U	7/.0179 in. silver coated copper covered steel	F-1	0.285	Silver covered copper, single braid		0.410	0.120	75.0	20.5	5,000	Similar to RG-11A/U except cable core is teflon

Table 6-2. Guide to Selection of Preferred RF Cables (Continued)

Class of cables	JAN Type	Inner conductor	Dielectric material	Nominal diameter of dielectric	Shielding braid	Protective covering	Nominal over-all diameter	Weight	Approx-imate imped-ance	Nominal capaci-tance	Maximum operating voltage	Remarks
				Inch			Inch	lb/ft	Ohms	μμf/ft	Volts/(rms)	Remarks
HIGH TEMPERATURE	RG-211A/U	.190 in. copper	F-1	0.620	Copper, single braid		0.730	0.450	50.0	29.0	7,000	Semi-flexible cable operating at temperatures -55° to 200° C. Formerly RG-117A/U.
	RG-225/U	7/.0312 in. silvered copper	F-1	0.285	Silver covered copper; double braid	Teflon tape moisture seal with double braid type V jacket	0.430	0.176	50.0	29.5	5,000	Semi-flexible cable operating at temperatures -55° to 200° C. Formerly RG-87A/U.
	RG-226/U	19/.0254 in. silver covered copper wire	F-2	0.370	Copper; double braid		0.500	0.247	50.0	29.0	7,000	Double braid medium size cable for use where expansion and contraction are a major problem. Formerly RG-94A/U.
	RG-227/U	7/.0312 in. silvered copper	F-1	0.285	Silver covered copper; double braid	Teflon tape moisture seal with double braid type V jacket with armor	0.490	0.224	50.0	29.5	5,000	Same as RG-225/U but with armor. Formerly RG-116/U.
	RG-228A/U	.190 in. copper	F-1	0.620	Copper; single braid		0.795	0.600	50.0	29.0	7,000	Same as RG-211A/U but with armor. Formerly RG-118A/U.
PULSE	RG-25A/U	19/.0117 in. tinned copper	E	0.288	Tinned copper double braid	IV	0.505	0.205	48.0	50.0	10,000	High voltage cable
	RG-26A/U	19/.0117 in. tinned copper	E	0.288	Tinned copper single braid	IV with armor	0.505	0.189	48.0	50.0	10,000	High voltage cable
	RG-27A/U	19/.0185 in. tinned copper	D	0.455	Tinned copper single braid	IV with armor	0.670	0.304	48.0	50.0	15,000 peak	Large size cable
	RG-28B/U	19/.0185 in. tinned copper	D	0.455	Inner tinned copper; outer galv. steel	IV	0.750	0.370	48.0	50.0	15,000 peak	Large size cable
	RG-64A/U	19/.0117 in. tinned copper	E	0.288	Tinned copper double braid	IV	0.475 (max)	0.205	48.0	50.0	10,000	Medium size cable
	RG-88/U	19/.0117 in. tinned copper	E	0.288	Tinned copper Four braids	IIa	0.515	---	48.0	50.0	10,000	Four braid, medium size; multi-shielded high voltage cable
	RG-156/U	7/21 AWG tinned copper	First layer A, second layer H.	0.285	Inner, tinned copper;	IIa	0.540	0.211	50.0	30.0	10,000	Taped inner layers, first layer type K and second layer type A-1R, between the outer braid of the outer conductor and the tinned copper shield. Tri-axial pulse cables.
	RG-157/U	19/24 AWG tinned copper	First layer H, second layer A, third layer H.	0.455	outer, galvanized steel. Double braid	IIa	0.725	0.317	50.0	38.0	15,000	
	RG-158/U	37/21 AWG tinned copper	First layer H, second layer A, third layer H.	0.455	Tinned copper outer shield	IIa	0.725	0.380	25.0	78.0	15,000	

Table 6-2. Guide to Selection of Preferred RF Cables (Continued)

Class of cables	JAN type	Inner conductor	Dielectric material	Nominal diameter of dielectric	Shielding braid	Protective covering	Nominal over-all diameter	Weight	Approximate impedance	Nominal capacitance	Maximum operating voltage	Remarks
				Inch			Inch	lb/ft	Ohms	$\mu\mu f/ft$	Volts/(rms)	
PULSE	RG-190/U	19/0.0117 in. tinned copper	First layer H, second layer J, third layer H.	0.380	Inner, tinned copper;	VIII over one wrap of type K	0.700	0.353	50.0	50.0	15,000	Taped inner layers, 2 wraps of type K and 2 wraps of type L, between the outer braid and tinned copper shield.
PULSE	RG-191/U	30 AWG tinned copper. Single braid over supporting elements 0.485 in. max	First layer H, second layer J, third layer H.	1.065	outer, galvanized steel. Double braid. Tinned copper shield	VIII over one wrap of type K	1.460	1.469	25.0	85.0	15,000	Pulse cable
SPECIAL CHARACTERISTICS	RG-22B/U	Two conductors 7/.0152 in. copper	A	0.285	Tinned copper; double braid	IIa	0.420	0.116	95.0	16.0	1,000	Small size, balanced, twin conductor cable
	RG-62A/U	.0253 in. solid copper-weld	A	0.146	Copper; single braid	IIa	0.242	0.382	93.0	14.5	750	
	RG-63B/U	.0253 in. copper covered steel	A	0.285	Copper; single braid	IIa	0.405	0.082	125.0	10.0	1,000	Medium size, low capacitance air-spaced cable
	RG-65A/U	No. 32 formax F .128 in. dia. (helix)	A	0.285	Copper; single braid	IIa	0.405	0.096	950.0	44.0	1,000	High impedance video cable, high delay line
	RG-71B/U	.0253 in. copper covered steel	A	0.146	Tinned copper; double braid	IIIa	0.250 (max)	---	93.0	14.5	750	Low capacitance cable
	RG-79B/U	.0253 in. copper covered steel	A	0.285	Copper; single braid	IIa with armor	0.475 (max)	0.138	125.0	10.0	1,000	Same as RG-63B/U but with armor
	RG-111A/U	Each conductor 7/.0152 in. copper	A	0.285	Tinned copper; double braid	IIa with armor	0.490 (max)	0.145	95.0	16.0	1,000	Same as RG-22B/U but with armor
	RG-126/U	7/.0203 in. Karma wire	F-1	0.185	Karma wire; single braid	Teflon tape moisture seal with double braid type V jacket	0.280	0.076	50.0	29.0	3,000	High attenuation cable
	RG-130/U	Each conductor 7/.0285 in. plain copper wire	A	0.472	Tinned copper; single braid	I	0.625	0.220	95.0	17.0	8,000	Same as RG-57/U, except inner conductors twisted to improve flexibility
	RG-131/U	Each conductor 7/.0285 in. plain copper wire	A	0.472	Tinned copper; single braid	I with aluminum armor	0.710	0.295	95.0	17.0	8,000	Same as RG-130/U but with armor

107

Table 6-2. Guide to Selection of Preferred RF Cables (Continued)

Class of cables	JAN type	Inner conductor	Dielectric material	Nominal diameter of dielectric	Shielding braid	Protective covering	Nominal over-all diameter	Weight	Approximate impedance	Nominal capacitance	Maximum operating voltage	Remarks
				Inch			Inch	lb/ft	Ohms	$\mu\mu$f/ft	Volts(rms)	
SPECIAL CHARCTERISTICS	RG-181/U	Two conductors 7/26 AWG copper	A	0.210	Copper, inner braids. Copper common braid	IIa	0.640	---	125.0	12	3,500	Filled to round transmission unbalance cable. Twin-coaxial.
	RG-187A/U	7/.004 in. annealed silver covered copper covered steel wire	F-1	0.060	Silvered copper; single braid	VII	0.110	---	75.0	---	1,200	High temperature miniaturized cable
	RG-188A/U	7/.0067 in. annealed silver covered copper covered steel wire	F-1	0.060	Silver covered copper; single braid	VII	0.110	---	50.0	---	1,200	High temperature miniaturized cable
	RG-195A/U	7/.004 in. annealed silver covered copper covered steel wire	F-1	0.102	Silver covered copper, single braid	VII	0.155	---	95.0	---	1,500	High temperature miniaturized cable
	RG-196A/U	7/.004 in. annealed silver covered copper covered steel wire	F-1	0.034	Silver covered copper; single braid	VII	0.080	---	50.0	---	1,000	High temperature miniaturized cable

Dielectric materials:

A Polyethylene
D Layer of synthetic rubber between two layers of conducting rubber
E Layer of conducting rubber plus two layers of synthetic rubber
F-1 Teflon (solid)
F-2 Teflon (semi-solid or taped)
H Conducting synthetic rubber
J Insulating Butyl-rubber

NOTE 1. Requirements for listed cables are in Specification MIL-C-17

Jacket types

I. Polyvinyl chloride (colored black)
IIa. Noncontaminating synthetic resin
IIIa. Noncontaminating synthetic resin (colored black)
IV. Chloroprene
V. Fiberglass, silicone-impregnated varnish
VII. Polytetrufluoroethylene
VIII. Polychloroprene

(4) Power Handling Capability. The average RF power than can be transmitted through a coaxial cable is dependent upon the temperature rise that can be tolerated within the cable and not cause insulation resistance breakdown. The heating effect in coaxial cable is caused by electrical losses in the center conductor, the shield, and the dielectric material. The power rating of a coaxial cable is defined as the input power that will produce a maximum safe center conductor temperature under steady-state conditions when the cable is terminated in its characteristic impedance.

Polyethylene dielectric flexible cables are used almost exclusively when the maximum center conductor temperature will not exceed 85° C (185° F) (ref. 16). Cable type RG-212/U, -213/U, and -214/U are typical of this group.

Teflon dielectric flexible cables are normally used in applications when the center conductor temperature rise is expected to range from 85° to 250°C (185° to 482° F) (ref. 16). Cable types RG-117/U, -118/U, and -119/U are typical of this group.

Table 6-2 categorizes the coaxial cable types as "general purpose," "special characteristics," "high temperature," and "pulse." The table may serve as a guide for the selection of transmission lines to meet specific requirements.

Some recently developed semi-flexible coaxial cables not listed in table 6-2 have high power ratings and have been put to Navy use. The HF Transmitter Facility, Naval Communications Station, Northwest Cape, Australia, is a case in point. This Facility uses RG-367/U, a 5-inch semi-flexible air dielectric cable, in a 200 kW (PEP) application, and also uses RG-322/U, a 3-inch cable, similarly constructed, for the 40 kW (PEP) transmitter system. Both transmission line configurations are operated as dry-air pressurized systems.

The power rating of a coaxial cable should be carefully evaluated against the anticipated operational environment. Some of the factors which can influence power ratings follow:

(a) VSWR. A mismatch between load and line impedance will produce standing waves along the line and will limit the amount of power than can be transmitted. In such a case, the average power rating of the line should be derated to compensate for the VSWR as follows:

$$\text{Derated Power} = \frac{\text{Rated Power}}{\text{VSWR}} \qquad (6\text{-}5)$$

(b) Modulation. Amplitude modulation of the transmitter also causes the power input to exceed the cable power handling capability because sideband power is added to the initial carrier power. In the case of amplitude modulation, the total power transmitted is:

$$P_{\text{total}} = P_{\text{carrier}} \left(1 + \frac{\%\ \text{Modulation}}{200}\right) \qquad (6\text{-}6)$$

Therefore, the power rating should be reduced by the factor:

$$\frac{1}{1 + \frac{\%\ \text{Mod}}{200}} \qquad (6\text{-}7)$$

For military applications, modulation of 40 percent is used as a standard. Therefore, the allowable power would be:

$$\text{Derated Power} = \frac{\text{Rated Power}}{1.2}$$

(c) Duty Cycle. Duty cycle refers to the percentage of time that power is applied to the cable. Since the basic power rating applies to a steady-state condition, a minor upgrading in cable power rating may be applied when transmitters are on the air only intermittently, or where modulation is applied only occasionally. However, the manufacturer's specifications for the particular cable must be carefully checked to determine to what extent overloading in this manner is permissible.

(d) Frequency. Dielectric absorption (i.e., dielectric heating) increases as frequency is increased. Because of this, frequency is a factor in the rating of coaxial cable. For some solid dielectrics, there are charts available that give approximate cable power rating adjustments, provided the power rating at one frequency is known (ref. 16).

(e) Location. Most coaxial transmission lines are buried because burial limits the amount of temperature variation caused by external conditions and affords a degree of physical protection. For adequate heat dissipation, lines buried in a common trench should be separated as recommended in paragraph 6.1.2.b(5).

b. Coaxial Cable Installation Considerations. Installation considerations for coaxial transmission lines are partly dependent upon the individual requirements and environmental factors at each site. Basic considerations are:

(1) Transmission Line Length. If other siting considerations permit, the higher frequency antennas should be located nearest the transmitter or receiver building (since attenuation losses increase with line-length and frequency).

(2) Cable Storage. Cable-ends are to remain sealed during storage, and until final permanent connections are made, to prevent moisture and dirt from entering the cable.

(3) Cable Bending Radii. Bending radii must not be smaller than ten times the cable diameter, and the bend should be in one direction only (no reversals). If a degree of flexure is considered necessary, cable that provides the adequate inner conductor and shield flexibility, and dielectric elasticity, should be selected. Right angle changes of direction in rigid and semi-flexible cable should be accomplished only by cutting the cable and installing appropriate flanges, elbows, and fittings.

(4) Connecting Cable Lengths. A continuous length of coaxial cable should be used for the entire run if at all possible. When this is not possible, approved splicing kits available from cable manufacturers should be used to splice the cables.

(5) Trenching and Cable Placement. When coaxial cable is to be buried, the trench depth depends upon soil conditions, the frost line, and upon other uses of the land area through which the trench must pass. Usually a depth of 2-1/2 feet provides sufficient cable protection. Pending the development of specific criteria for cable separation distances, the general rule to ensure adequate separation is to separate cables by a distance equal to twice the diameter of the largest cable. Figure 6-4 illustrates a typical trench layout. Sand should be used as the cable bed in case the trench bottom is rocky or uneven, and should cover the cables to a depth of 6 inches. A 1-1/2 inch plank, treated to resist insect damage and burial deterioration, is placed on top of the sand as added protection. The remainder of the trench is then tamped and backfilled.

If buried lines are to cross under primary access roads, adequate provision for maintenance and protection from physical damage must be made. Cable to be routed under traffic areas other than primary access roads should be placed in galvanized iron conduit buried at least 30 inches.

Where buried lines are to be routed under cultivated fields, an added safety margin of trench depth should be considered.

(6) Cable Route Marking. Buried transmission line routes must be clearly identified with permanent concrete or steel markers. These markers should be placed at each road crossing, bend or splice, and at 200-foot intervals along the transmission line route. One type of marking stake is shown in figure 6-5.

(7) Cable and Cable Fittings. All coaxial cables and fittings are to be selected in conformance with the standards in reference 16.

(8) Above-Ground Installation of Transmission Lines. Where soil or terrain conditions make excavation of trenches impractical, coaxial transmission lines can be "installed" above ground in a manner that affords protection similar to burial. One line, or a group of lines, can be placed on a layer of sand approximately 3 inches deep on the ground surface between the antenna and the transmitter or receiver building. The line and sand bed are then covered with concrete covers for the length of the line. The same general considerations for cable separation, identification and access apply to above-ground installation as for below-ground installation. Plans and details for one method of above ground transmission line installation are given in NAVFAC Atlantic Division Drawing 1198055.

6.2 DISSIPATION DEVICES

In HF antenna systems, dissipation devices may be used to provide a substitute or dummy load to absorb transmitter power, or to provide a terminating impedance for traveling-wave antennas.

A dummy load presents to a transmitter an impedance equal to that of the antenna, and is used to absorb the transmitter power when antenna radiation is undesirable.

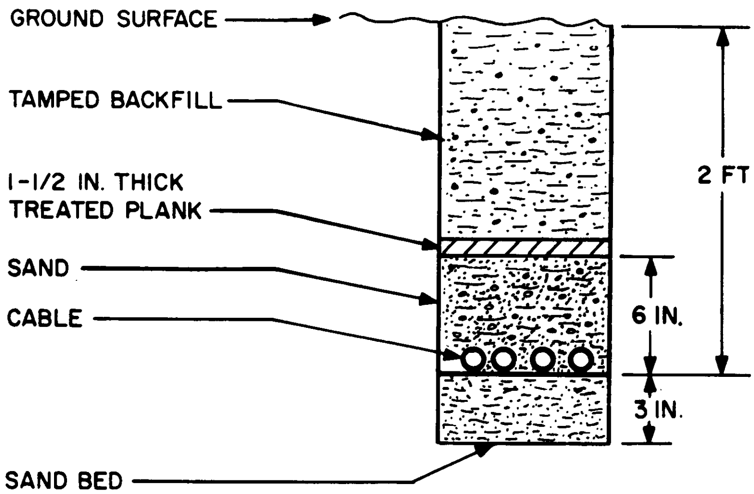

Figure 6-4. Cable Trench Layout

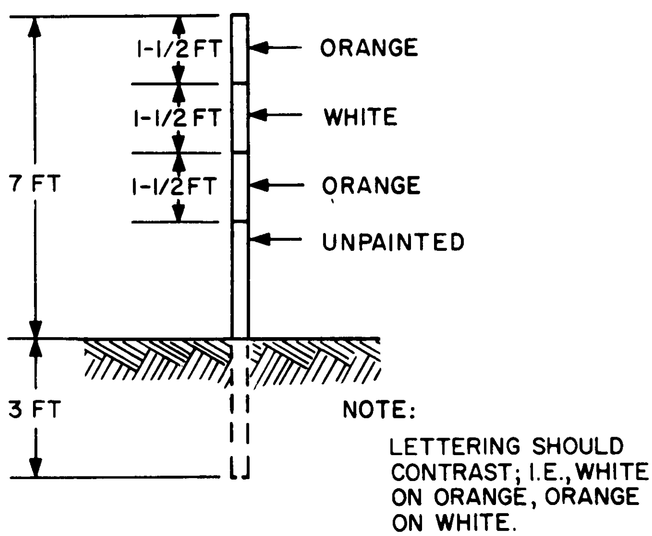

Figure 6-5. Buried Cable Marker

A termination device is installed at the forward end of an antenna, and is used to absorb power that would otherwise cause reflected waves. This terminating impedance is a major consideration for rhombic and vee antennas. Although the forward direction radiation pattern is little affected by the presence or absence of the termination, radiation in the backward direction is directly dependent upon whether or not power is absorbed at the forward end of the antenna. If no termination is used, about one-half of the transmitted power will be radiated in the forward traveling wave, and one-half in the reflected wave. On the other hand, a resistive termination at the forward end of the antenna will absorb the power that would be radiated in the reflected wave. The resultant backlobe suppression gives the desired unidirectional pattern, reduces undesirable radiation, and thereby reduces the probability of interference with other nearby antennas and communications devices.

There are two basic types of dissipation devices: distributed and lumped.

6.2.1 Distributed Dissipation Devices

Distributed dissipation devices, commonly known as dissipation lines, have their attenuating resistance distributed along the length of the line. These dissipation lines are actually transmission lines specially designed to have a high attenuation per unit length. Dissipation lines, used primarily to provide termination impedance for traveling-wave antennas, are capable of absorbing the output of very high power transmitters.

a. Physical and Electrical Characteristics. Dissipation lines are usually fabricated from No. 10 to No. 14 AWG solid, stainless steel wire. These wire sizes and types provide the heat dissipation and impedance characteristics required, and they are highly resistant to weather damage. The dissipation line is shorted and grounded at the end distant from the power source to terminate the line at zero potential. Figure 6-6 illustrates a typical rhombic antenna dissipation line arrangement. Detailed construction and installation plans may be found in NAVELEX Drawing RW 66D 295.

The following characteristics are usually specified for dissipation lines:

(1) Height. Minimum height above ground should be 12 feet to prevent personnel from contacting the line.

(2) Attenuation and Dissipation. Lines for low- and medium-power transmitters are inexpensive. For this reason they should be designed to dissipate the full, overdriven transmitter output. Lines for transmitters operating in excess of 50 kW average power should be designed on the basis of rated average power and the radiation efficiency at planned operating frequencies.

(3) Characteristic Impedance. Characteristic impedance is normally 600 ohms for balanced configurations, but it may vary according to application.

(4) VSWR. Should not exceed 1.1:1 over the operating frequency band.

(5) Wire Spacing. Spacing between individual wires of the dissipation line must be maintained in the same manner as the open-wire transmission line to ensure a constant characteristic impedance.

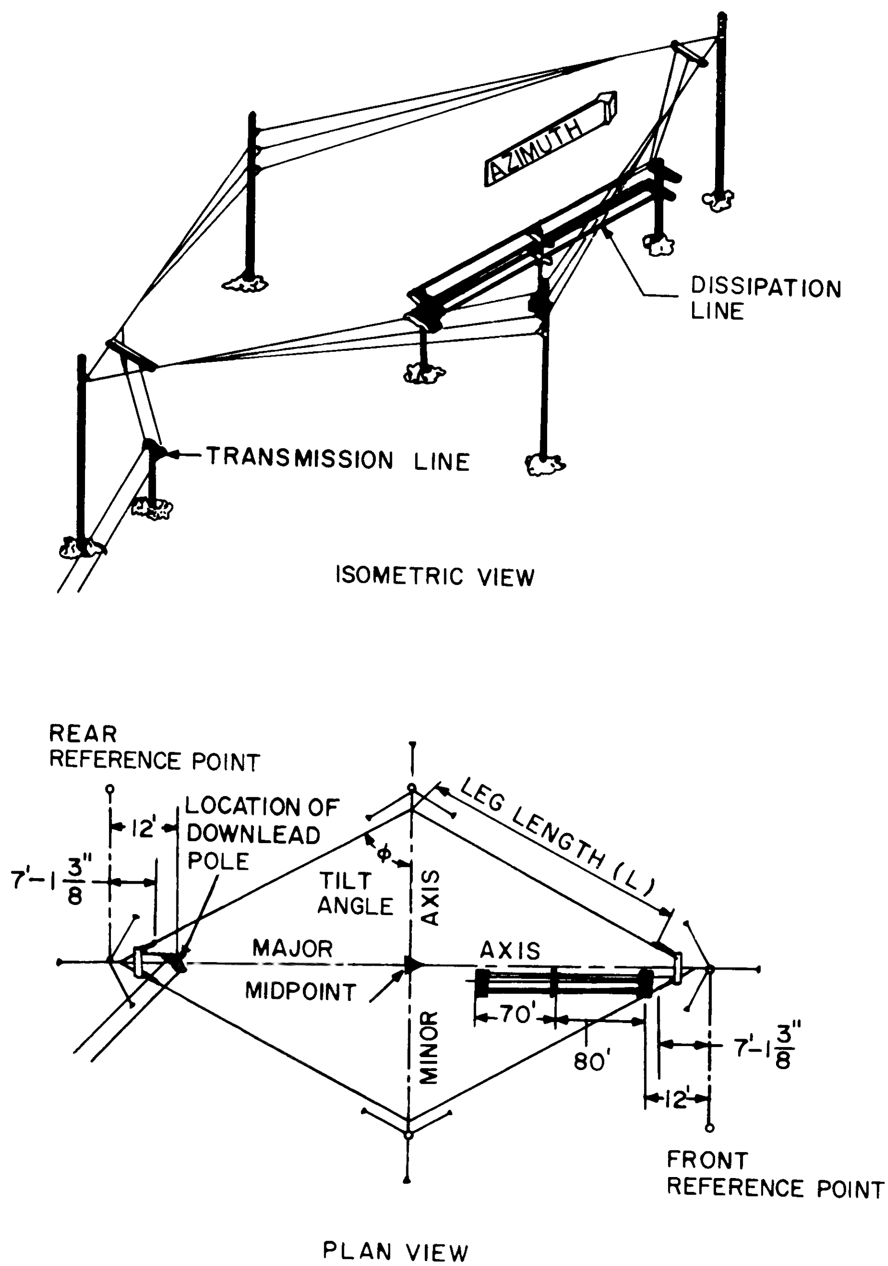

Figure 6-6. Typical Dissipation Line Arrangement

(6) Balance. Line balance requirements may vary according to the application, but balance must be within 10 percent for rhombic antennas.

6.2.2 Lumped Dissipation Devices

Lumped devices provide a means of termination and power dissipation in a manner similar to that of a dissipation line. The principal difference is that in a lumped device the attenuating resistance is lumped and installed in an enclosure which is located at the antenna or in a position convenient to the transmitter output switching matrix, depending on whether it is to serve as an antenna termination or a transmitter dummy load.

a. Physical and Electrical Characteristics. Lumped devices are basically non-inductive resistors and are available commercially in power ratings from low to very high power ranges. The lumped devices used in very high power transmitter systems normally require a cooling system for effective heat dissipation. For most dummy load applications, lumped attenuation devices may be procured as auxiliary components of the transmitter, with selection being made on the basis of transmitter characteristics: power rating, characteristic impedance, VSWR, frequency range, etc.

Generally, the cost of lumped dissipation devices does not compare favorably with the cost of dissipation lines for application in the high and very high power ranges because sophisticated cooling systems are required to maintain resistive characteristics of the load. For this reason, consideration should be given to a combination of lumped and distributed devices that will overcome distributed capacity effects. In this type of combined termination impedance, a dissipation line can be truncated and terminated in a lower power lumped device. This type of dissipation arrangement is capable of providing the necessary power dissipation, impedance, VSWR, frequency range, and balance characteristics.

For termination impedance applications, the following characteristics are usually specified for lumped dissipation devices:

(1) Attenuation and Dissipation. Lumped devices should be capable of dissipating the average power output of the associated transmitter. These attenuating resistors must also have a high enough impulse rating to prevent changing resistance caused by induced currents from lightning.

(2) Characteristic Impedance. Characteristic impedance is normally either 50 or 600 ohms according to the impedance level of the installation.

(3) VSWR. The VSWR should not exceed 1.1:1 over the operating frequency band.

(4) Balance. Balance should be within 10 percent for rhombic antennas.

6.3 LIGHTNING PROTECTION

Since antennas are usually located at a height above other structures at a transmitter or receiver site, they are likely to be in the path of lightning discharges to earth. They should, therefore, have suitable direct-stroke lightning protection as well as a static-charge drain so that such a lightning discharge will not pass through vulnerable system components. Protection systems should be capable of preventing lightning strokes from breaking down dielectric materials in antennas and transmission lines, and should also prevent damage to all other components in the transmitting and receiving systems. In any system of lightning protection, a path to ground must be provided that will offer less resistance and inductance than any other alternate paths.

Grounded metal towers and support structures create a lightning protection effect called the cone of protection. Since a direct lightning stroke tends to take the lowest resistance path to ground, these tall, grounded structures will draw lightning strokes and thus protect surrounding objects from a direct hit. This protection is usually effective for objects within a cone centered on the grounded structure and with a base radius of one to two times the tower height. Thus, metal towers can provide a degree of protection for the antennas they support as well as for transmission lines within the immediate area.

6.3.1 Lightning Rod Systems

Lightning rod systems are relatively simple protective grounding systems used to provide a low-resistance, low-inductance path to the earth. Their principal application is on wooden support poles. A typical installation consists of a lightning rod mounted on the top of the pole, a down-conductor wire, and a ground rod as shown in figure 6-7.

Lightning rod systems are not necessary on metal support towers if the resistance of the tower structural members, measured from top-to-base, is 10 ohms or less. A tower may be grounded by connecting any convenient point on the tower to a ground rod of the type shown in figure 6-7.

A satisfactory lightning rod system can be obtained by adhering to the following:

a. Lightning Rod. Fabricate the lightning rod from copper or copper-clad steel rod at least 3/4-inch in diameter, and 5 feet long. Install the rod so that it will project two feet or more above the top of the pole.

b. Down-Conductor Wire. For the down-conductor wire, use at least No. 2 AWG copper or copper-clad steel wire to afford the necessary low-resistance, low-inductance path to ground.

The down-conductor wire must be a straight, continuous length from the lightning rod connection to the ground rod. On wooden poles, this continuous length should never be broken up with discharge gaps since an arcing gap could set the pole afire. At connection points, and points where changes of direction are unavoidable, bending radii of the wire must be at least 8 inches, and the bend must be no greater than 90°.

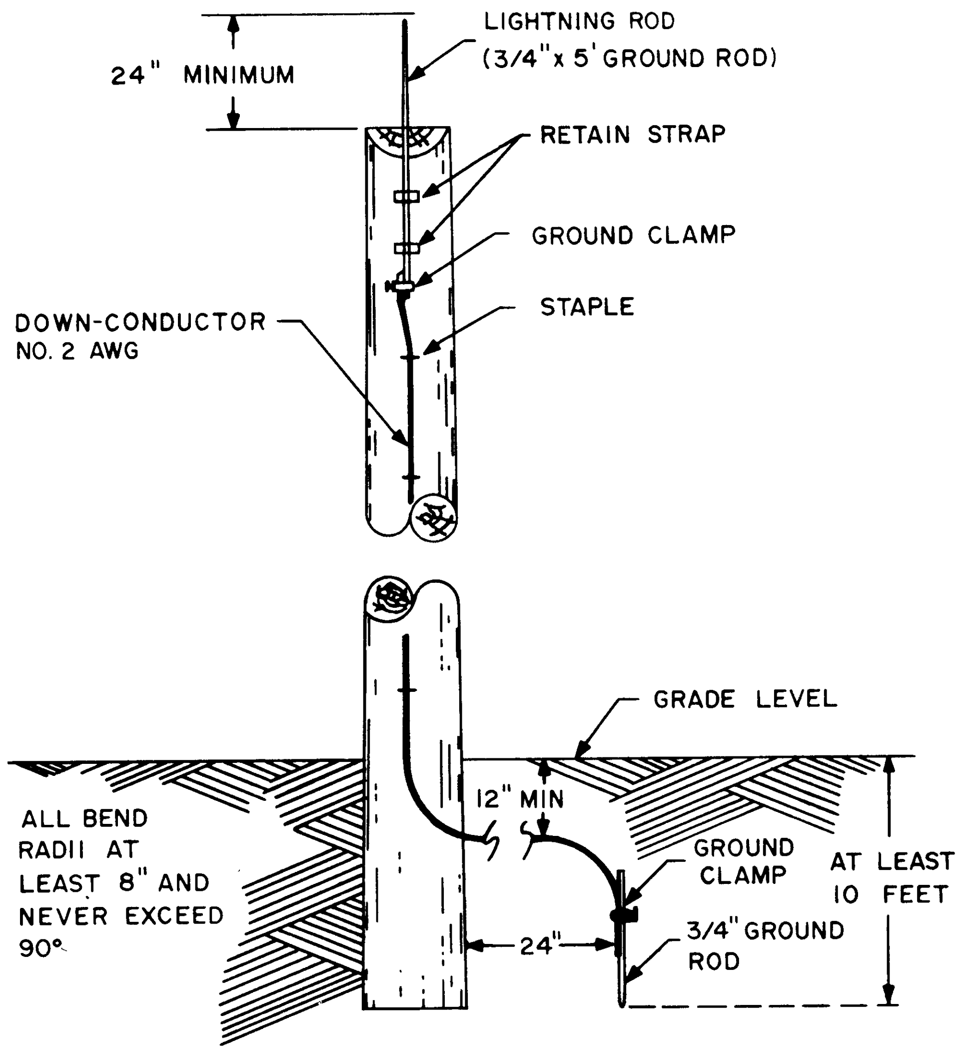

Figure 6-7. Typical Lightning Rod and Down-Conductor Arrangement

c. Other Metal Objects. If other metal objects such as hoisting-arms or obstruction lights, are installed on top of the pole, ground them by connecting them to the down-conductor with wire of the same size and type as the down-conductor. Run power wiring to these objects in metal conduit bonded to the down-conductor at random intervals of not more than 10 feet.

d. Connectors. Use copper or bronze bolted-type connectors to secure the down-conductor to the lightning and ground rods.

e. Ground Rod. Fabricate the ground rod from copper-clad steel rod at least 3/4 inches in diameter and 10 feet long. Ideally, the rod should be set in the ground so that its entire length is below grade as shown in figure 6-7. In the event that the desired depth cannot be reached and the depth of refusal is so shallow that the ground rod will be ineffective, an acceptable protective ground termination can be made by wrapping at least 25 feet of No. 2 AWG (or larger) copper wire around the base of the structure at the lowest point possible below grade.

Interconnection of the down-conductor and ground rod should be made below grade as shown in figure 6-7.

6.3.2 Discharge Gaps

Discharge gaps, installed at the junction of the antenna and transmission line, are used to protect HF antennas and their associated components against high-voltage surges resulting from lightning. Gaps should also be installed across the terminating resistance of terminated antennas and at the point of building entry of open-wire transmission lines.

There are three basic types of discharge gaps: point, ball, and horn gap. All three serve the same purpose, in that the gap resistance breaks down and permits current flow to the earth in the event of a lightning strike, thus providing a degree of over-voltage and current protection to connected equipment.

The point gap device will break down at a lower voltage than the others, so it is generally well-suited for receiving antennas. The ball gap has roughly three times the breakdown voltage rating of the point gap, and it may be used on either receiving or transmitting antennas. The horn gap is the most commonly used of the three types. It has approximately the same breakdown voltage rating as the ball gap, and it is also self-quenching; that is, an arc across the electrodes will not be sustained by transmitter RF power.

A typical horn gap installation for antenna down-leads is illustrated in figure 6-8.

The gap electrodes are made from nickel-plated brass rod or hard-drawn solid copper at least 1/4 inch thick, and the electrodes are connected to antenna down-leads, down-conductor wires, or other conductors, with copper or bronze bolt-type connectors. The requirements for the down-conductor and the ground rod are the same as those for a lightning rod system.

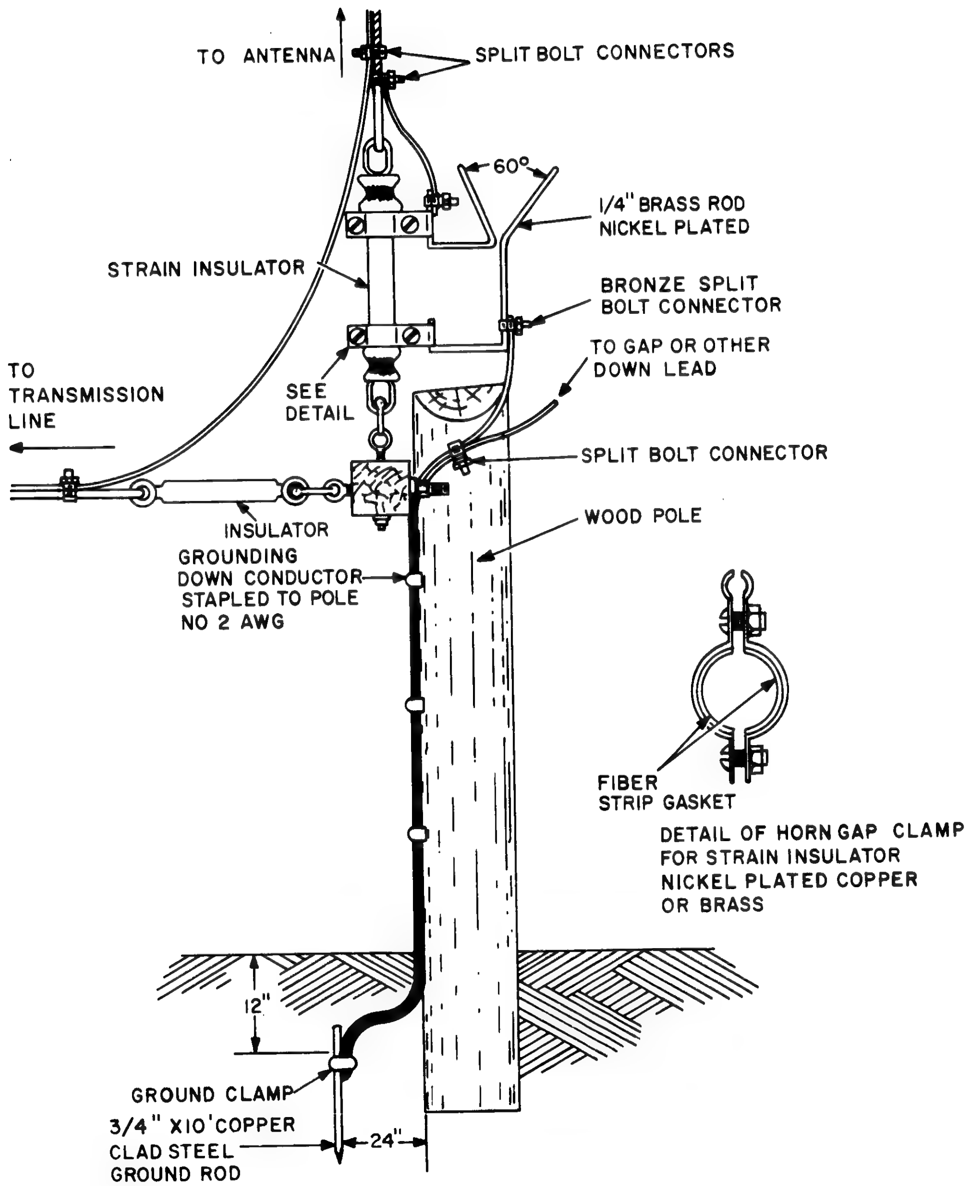

Figure 6-8. Typical Horn Gap Arrangement for Antennas

The minimum voltage at which the gap will break down and divert current flow to ground is determined by electrode spacing. The desired breakdown voltage is attained by spacing the electrodes at the distance for which the full power output of the transmitter (at 100 percent modulation) produces an arc and then increasing the spacing an additional 1/4 inch.

6.4 GUYWIRES AND INSULATORS

In any HF antenna system, guys and insulators can affect antenna operating efficiency. The type of guys used (metal wire or non-conducting materials), placement of guys relative to radiation fields, and positioning of insulators on metal guys must be considered in order to achieve desired antenna efficiency. Most HF antenna poles and metal towers are supported by several guys attached to different points on the structure and anchored in the ground. Guys made from metal wire may be resonant at some operating frequencies and, therefore, may act as reradiating or parasitic antennas. Detrimental effects of guywires usually can be prevented by observing the following precautions:

a. Guywire Location. Place guywires in a location where the radiation field from the antenna is weakest.

b. Break-Up Insulators. Place break-up insulators at random intervals on the guywire to interrupt the resonant lengths. This is particularly important if the guys cannot be located in a weak radiation field. The longest uninterrupted length should not exceed 0.1 wavelength at the highest design frequency of the antenna.

c. Non-Conducting Guys. In some antenna installations, the use of break-up insulators to prevent resonance of metal guys may be expensive and impractical. If a large number of break-up insulators is required, consideration should be given to using guys made from nonconducting materials. Although the cost of nonconducting guys is normally more than for stranded steel wire of comparable strength, the overall cost, with the high tensile strength insulators eliminated, could favor nonconducting materials. Mylar and fiberglass are suitable nonconducting materials for guywire applications. Manila rope may also be used, but only for temporary guying arrangements.

6.5 BALUNS

A balun is a type of transformer that can be used both for impedance matching and for interconnecting balanced and unbalanced transmission lines. They are often used for balanced-to-unbalanced interconnections regardless of whether an impedance transformation is required to match impedances for maximum power transfer. That is, the impedances of the interconnected lines, or other components, may be equal or they may differ. In the case of differing impedances, the necessary impedance transformation is incorporated in the balun.

A core-type RF balun is used in most Navy HF antenna systems to attain the desired impedance transformation between balanced antennas (typically 600 ohms) and unbalanced transmission lines (50 ohms). Other types of baluns are described in reference 14.

Both transmitting and receiving antennas employ baluns for the impedance transformation at the interconnection point between the antenna and the transmission line. Baluns can also be used at building entry points to change from balanced open-wire lines to coaxial lines; however, most Navy transmitter sites that are still using open-wire lines have them run directly into the transmitter.

Some antennas are purchased complete with balun matching devices. In such cases, the antenna manufacturer selects a device in conformance with Navy-furnished system performance specifications.

Other antennas, notably rhombics, use HF balun transformers such as the CU-1699/FRT Line Coupler for transmitting, and the CU-1706/FRR for receiving applications. Standard installation plans for balun transformers on both transmitting and receiving antennas are contained in NAVELEX Drawing RW 66D 295.

6.5.1 Transmitting Balun Performance Specifications

Typical system performance specifications for transmitting baluns are as follows:

Power handling capability	Transmitter continuous average power output with load VSWR of 2.5:1 when loaded with "white noise" (noise with a spectrum continuous and uniform as a function of frequency), and when intermodulation requirements are met.
Frequency range	The design frequency band of the antenna.
Impedance transformation	Dictated by system design; usually a 12:1 balance-to-unbalance ratio.
Insertion VSWR	1.25:1 maximum (with 1:1 VSWR load).
Load VSWR	2.5:1 maximum (continuous operation).
Insertion loss	0.15 dB maximum over the operating frequency range at rated power.
Unbalance	5 percent maximum over the operating frequency range.
Intermodulation	50 dB minimum below transmitter average power output (with load VSWR of 2.5:1 and loaded to rated power with "white noise").

The CU-1699/FRT is typical of balun transformers which will meet the preceding performance specifications. It is an oil-filled transformer capable of operating from 2 to 32 MHz at power levels up to 50 kW (PEP). The transformer is contained in a cylindrical aluminum tank that is suitable for pole or tower mounting. Internal cooling is accomplished by natural convection with transformer oil. The transformer is cooled externally by natural convection of surrounding air.

6.5.2 Receiving Balun Performance Specifications

Receiving baluns are physically and electrically similar to transmitting baluns except for the smaller physical size and lower power handling capability. The following system performance specifications are typical:

Insertion loss and dynamic range	0.3 dB maximum over the operating frequency range (with an input between 2 microvolts and 2 volts).
Impedance transformation	12:1 over the operating frequency range.
Insertion VSWR	1.2:1 maximum over the operating frequency range.
Load VSWR	3:1 maximum over the operating frequency range.
Dynamic input range	60 dB minimum (at a 2-volt reference level).
Unbalance	5 percent maximum over the operating frequency range.
Intermodulation	50 dB minimum below the desired signal level over the operating frequency range.

The CU-1706/FRR is typical of receiving balun transformers that will meet the above performance specifications. It is capable of providing the necessary balance-to-unbalance transformation over a 4 to 24 MHz frequency range.

6.6 HF MULTICOUPLERS

Multicouplers are used in both transmitting and receiving applications to allow more effective utilization of available antennas. They permit the output of more than one transmitter to feed a single antenna and permit operation of as many as eight receivers from a single antenna with excellent RF signal quality.

Transmitting multicouplers are capable of providing separate impedance-matched paths for the transfer of RF power from two or more transmitters to a common antenna for simultaneous operation. The usual method of isolating one transmitter from another employs frequency-separating bandpass filters within the multicoupler as shown in figure 6-9.

All transmitting multicouplers are passive networks consisting of reactive and resistive elements in which no signal amplification occurs. Receiving multicouplers, on the other hand, may be either passive or active.

Passive multicouplers are not widely used in HF receiving systems because they do not amplify the RF input from the antenna, and because interchannel isolation is likely to drop below 40 dB if more than two output channels are coupled from the unit.

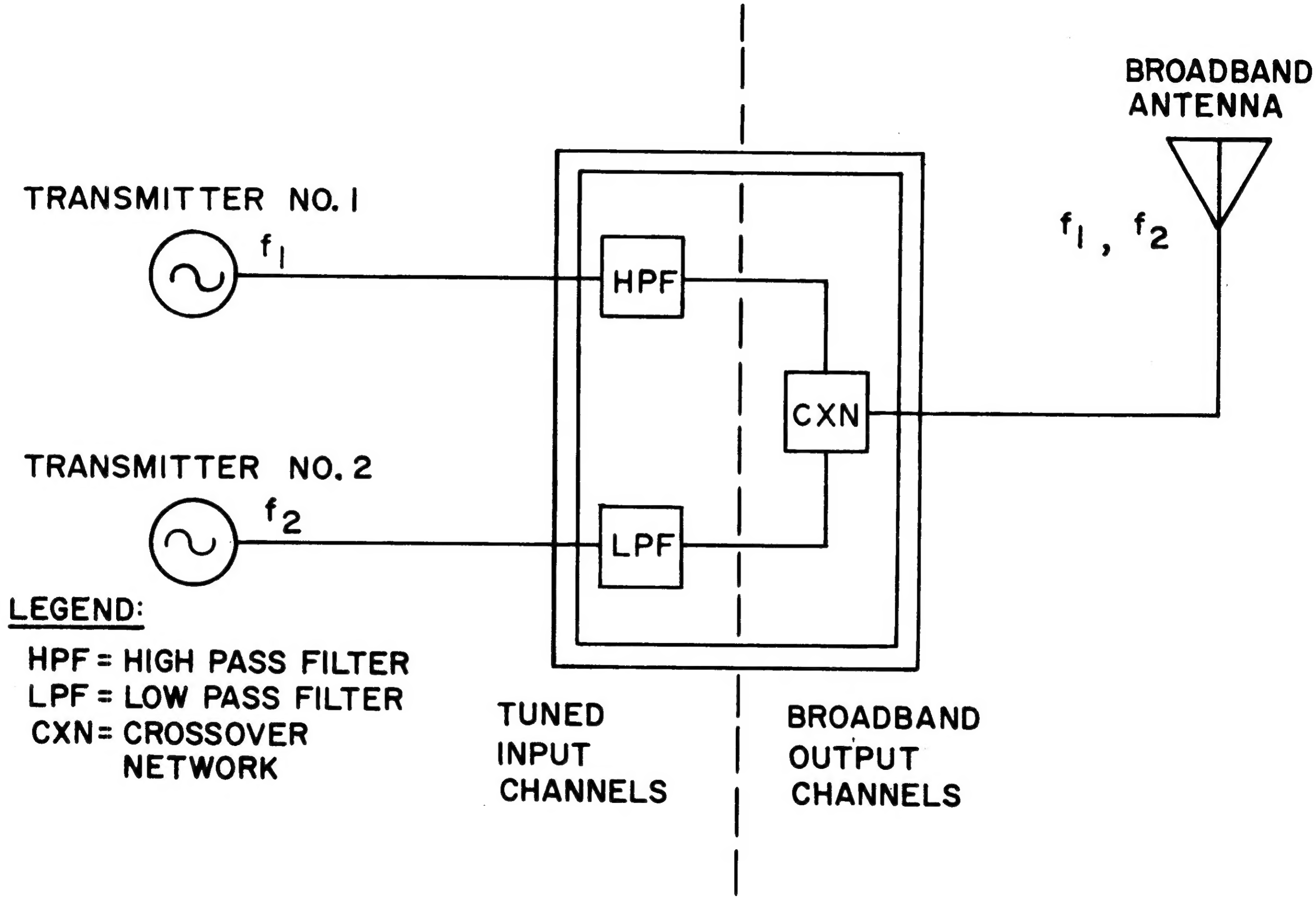

Figure 6-9. Typical Transmitting Multicoupler Arrangement

Active multicouplers such as the CU-656/U, which employs electron tube circuitry, and the CU-1382( )/FRR, a transistorized unit, are widely used in HF receiving systems. They are capable of power gains sufficient to compensate for line losses, usually from 1 to 3 dB over the 2 to 32 MHz frequency band, and they provide the correct impedance match between the transmission line and receivers. For the most part, procurement of HF receiving multicouplers is now limited to transistorized units that conform to MIL-A-28729A (EC), "Antenna Coupler Group (HF Broadband, Wide Dynamic Range)". A typical receiving multicoupler circuit flow diagram, showing one RF input and 8 outputs, is illustrated in figure 6-10.

6.6.1 Transmitting Multicoupler Performance Specifications

In most cases, transmitting multicouplers are selected as part of a transmitting system in conformance with Navy-furnished performance specifications. All transmitting multicouplers are required to meet the following minimum performance specifications:

Frequency range	All frequencies in the 2 to 30 MHz range regardless of the number of inputs.
Power handling capability	System rated power levels (with the load VSWR as high as 2.5:1).
Input and output impedance	50 ohms (unbalanced).
VSWR	1.2:1 maximum between the input channel and transmitter over the channel bandpass frequency.
Channel isolation	45 dB minimum between channels.
Insertion loss	0.5 dB maximum over the total passband (with a 1:1 insertion VSWR).

6.6.2 Receiving Multicoupler Performance Specifications

Active receiving multicouplers are required to meet the following minimum performance specifications:

Frequency range	2 to 30 MHz.
Impedance	50 ohms (unbalanced), input and output.
VSWR	2:1 maximum over the input frequency range.
Channel isolation	40 dB minimum between outputs.
Intermodulation	60 dB minimum below the output level (measured against a 0.5-volt input test signal).
Gain	Between 1 and 3 dB over the 2 to 30 MHz frequency range.

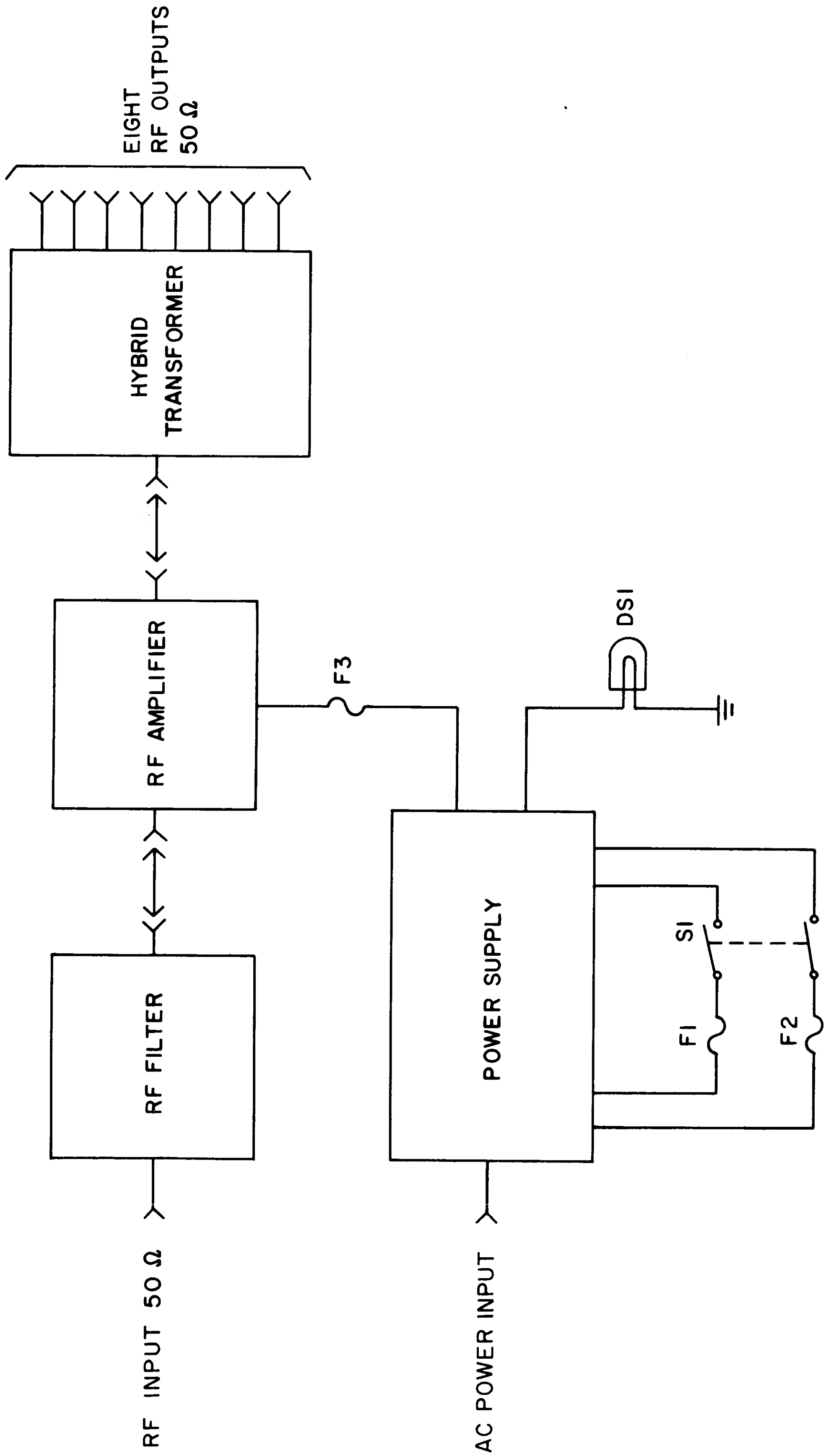

Figure 6-10. Typical Receiving Multicoupler Circuit Diagram